Table D-1
Results of Mercury Speciation Field Blanks at Site S2

Date	KCl Solution, μg	H_2O_2 Solution, μg	$KMnO_4$ Solution, μg
7/17/2002	0.04	<0.01	<0.01
7/18/2002	0.20	<0.01	0.37
7/19/2002	0.04	<0.01	0.09
7/20/2002	0.03	<0.01	0.05

Table D-2
Results of Mercury Speciation Field Spikes at Site S2

	KCl			H_2O_2 Solution			$KMnO_4$ Solution		
Date	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %
7/17/2002	9.95	10	99.51	0.96	1	96.05	8.49	10	84.85
7/17/2002	4.75	5	94.98	1.06	1	106.25	5.12	5	102.30
7/17/2002	9.37	10	93.69	2.13	2	106.51			
7/18/2002	10.92	10	109.20	1.04	1	103.60	5.02	5	100.40
7/18/2002	4.90	5	98.00	1.04	1	103.95	4.90	5	98.00
7/18/2002	9.80	10	98.00	2.24	2	112.18			
7/19/2002	9.46	10	94.64	1.02	1	101.89	4.98	5	99.60
7/19/2002	4.45	5	89.04	1.14	1	113.78	4.75	5	95.00
7/19/2002	9.02	10	90.16	2.33	2	116.75			

Table D-3
Results of Mercury Speciation Field Spikes at Site S4[a]

Date	KCl			$KMnO_4$ Solution		
	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %
9/11/2002	9.94	10	99.40	9.00	10	90.00
9/12/2002	9.65	10	96.50	9.53	10	95.30
9/13/2002	9.76	10	97.60	9.46	10	94.60

[a] Sampling at Site S4 was done by Western Kentucky University.

Table D-4
Results of Mercury Speciation Field Blanks at Site S5

Date	KCl Solution, μg	H_2O_2 Solution, μg	$KMnO_4$ Solution, μg
7/26/2002	0.18	<0.01	0.05
7/27/2002	0.05	0.01	0.08
7/28/2002	0.10	0.09	0.13
8/14/2002	0.04	<0.01	0.06
8/15/2002	0.05	<0.01	0.12
8/18/2002	0.06	<0.01	0.05
8/22/2002	<0.01	0.09	0.01

Table D-5
Results of Mercury Speciation Field Spikes at Site S5

Date	KCl			H_2O_2 Solution			$KMnO_4$ Solution		
	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %
7/26/2002	11.00	10	109.99	0.92	1	92.05	4.48	5	89.60
7/26/2002	5.24	5	104.83	0.81	1	81.20	4.69	5	93.80
7/26/2003	10.00	10	100.01	1.92	2	96.08			
7/27/2002	9.46	10	94.62	0.99	1	99.10	4.96	5	99.20
7/27/2002	4.82	5	96.37	1.98	2	99.10	4.73	5	94.60
7/27/2002	9.30	10	92.98						
7/28/2002	9.75	10	97.48	0.81	1	80.96	4.59	5	91.74
7/28/2002	4.39	5	87.85	0.87	1	86.72	5.13	5	102.60
7/28/2002	9.01	10	90.12	1.97	2	98.72			
8/14/2002	10.15	10	101.49	1.72	2	86.10	5.11	5	102.10
8/14/2002	5.53	5	110.63	2.00	2	99.90	4.75	5	94.90
8/14/2002	9.87	10	98.71	4.76	5	95.14			
8/15/2002	9.21	10	92.06	1.08	1	108.15	5.25	5	104.90
8/15/2002	7.03	7	100.48	1.13	1	112.65	5.16	5	103.10
8/15/2002	11.23	10	112.34	2.31	2	115.43			
8/18/2002	15.64	15	104.24	1.06	1	106.19	7.56	7	108.00
8/18/2002	10.61	10	106.14	0.87	1	86.92	7.84	8	98.00
8/18/2002	15.71	15	104.76	1.75	2	87.33			
8/21/2002	16.52	15	110.13	1.02	1	101.79	6.88	7	98.27
8/21/2002	16.52	15	110.13	1.21	1	121.29	10.62	10	106.21
8/21/2002	21.84	20	109.20	2.08	2	104.13			

Table D-6
Results of Mercury Speciation Field Blanks at Site S6

Date	KCl Solution, μg	H_2O_2 Solution, μg	$KMnO_4$ Solution, μg
9/23/2002	0.02	<0.01	0.12
9/24/2002	0.11	<0.01	0.15
9/26/2002	0.23	0.07	0.19
9/27/2002	0.04	<0.01	0.10
10/9/2002	0.05	<0.01	0.04
10/13/2002	0.03	0.01	<0.01
10/14/2002	<0.01	<0.01	<0.01
10/15/2002	0.11	0.11	0.09
10/18/2002	0.01	0.02	0.02
10/19/2002	<0.01	0.04	<0.01

Table D-7
Results of Mercury Speciation Field Spikes at Site S6

Date	KCl			H_2O_2 Solution			$KMnO_4$ Solution		
	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %	Measured Value, ppb	Spike, ppb	Spike Recovery, %
9/23/2002	10.68	10	106.79	0.83	1	82.93	5.15	5	103.01
9/23/2002	5.56	5	111.22	1.13	1	113.31	5.55	5	110.99
9/23/2002	10.46	10	104.61	2.12	2	106.10			
9/26/2002	3.23	3.4	94.96	1.04	1	103.89	12.47	11.6	107.47
9/26/2002	4.56	5	91.11	0.96	1	96.43	5.63	5	112.67
9/26/2002	10.13	10	101.27	1.58	2	78.93			
9/27/2002	12.42	11.6	107.09	0.97	1	96.75	5.31	5	106.13
9/27/2002	5.50	5	109.96	0.96	1	95.89	5.69	5	113.87
9/27/2002	11.10	10	110.98	1.75	2	87.63			
10/9/2002	4.35	5	87.02	0.88	1	87.73	4.57	5	91.36
10/9/2002	5.39	5	107.86	0.90	1	89.90	5.28	5	105.64
10/9/2002	10.91	10	109.09	1.86	2	93.16			
10/13/2002	4.76	5	95.26	0.89	1	89.33	4.91	5	98.20
10/13/2002	4.56	5	91.22	1.05	1	105.07	5.06	5	101.20
10/13/2002	11.06	10	110.57	1.94	2	96.94			
10/14/2002	5.68	5	113.68	1.05	1	104.81	5.20	5	103.90
10/14/2002	6.10	5	122.08	1.16	1	115.55	5.21	5	104.10
10/14/2002	11.82	10	118.16	2.34	2	116.99			
10/15/2002	4.98	5	99.69	1.18	1	118.20	4.68	5	93.62
10/15/2002	5.36	5	107.23	1.10	1	109.95	5.05	5	100.98
10/15/2002	10.98	10	109.76	1.98	2	98.85			
10/18/2002	5.41	5	108.28	1.39	1	138.56	5.35	5	107.08
10/18/2002	5.55	5	110.96	1.23	1	122.90	5.45	5	108.92
10/18/2002	11.11	10	111.06	2.18	2	109.22			
10/19/2002	5.58	5	111.58	1.64	1	163.57	6.09	5	121.76
10/19/2002	6.15	5	123.06	1.20	1	119.94	5.71	5	114.24
10/19/2002	11.08	10	110.81	2.53	2	126.47			

QA/QC Checks for Data Reduction and Validation

Data Reduction

Data reduction occurred in two phases. First, preliminary data reduction occurred on the job site. On-site data reduction may be performed by sampling and analytical personnel or by the team leaders. Preliminary calculations include velocity, moisture, stack gas flow, sample gas volume, percent-isokinetic sampling, and flue gas Hg concentrations. Calculations were performed using spreadsheets on a portable computer; some averaging was done with a calculator. Standardized spreadsheets were used.

The second phase of data reduction occurred after the team had left the job site. This included review of the field data and input of laboratory results to complete the calculated Hg concentrations for the coal and ash samples. In addition, the Hg speciation calculations that were done in the field were rechecked and put into a predefined data sheet. Equations to be used in the calculations were contained in the method.

Data Validation

All data, data entry, and calculations were double-checked by the originator and reviewed by a second person. Reviews included recalculation of results, data entry checks, and calculation of known and accepted data sets using the existing spreadsheet.

Sample Identification and Chain of Custody

Samples were identified with unique sample numbers and descriptive notations. Sample custody was maintained by EERC personnel; samples were stored and taken back to the EERC. Once the samples were received by the EERC laboratory, sample condition was checked and then logged into the EERC logging system.

Data sheets were kept in the custody of the originator or the program manager or in locked storage until returned to the office. The original data sheets were used for report preparation, and any additions were initialed and dated.

Personnel Responsibilities and Test Schedule

Test Site Organization

Each project comprised a team of personnel able to provide the expertise needed for project completion. The site-specific test plan (SSTP) that was provided to the company outlines the designated management, sampling, and plant personnel required for each project. The key roles of EERC project personnel for project completion are listed below:

- Project manager
- Field manager
- Principal investigator
- Project chemist
- Sample custodian
- Sampling technicians
- Mercury semicontinuous emission monitor (Hg SCEM) technicians

Test Preparations

Construction of Special Sampling Equipment and Modifications to the Facility

The correct length of sample probes was made prior to going into the field. No modifications were needed.

General Services Provided by the Facility

The facility provided safe access to suitable sample ports; process data; 110-V, 20-amp power at the sample locations; a suitable location to park test trailers; and power for the test trailers. In addition, the plant provided restrooms and a clean area for breaks or lunch. The facility was expected to provide the necessary safety training for the sampling team once they were on-site.

Access to Sampling Sites

Site visits were conducted to determine, among other things, that all sample ports were readily accessible. In addition, measurements were taken so that modifications to probes could be made prior to going into the field.

Sample Recovery Areas

The EERC provided test trailers to set up and tear down sample trains and do the analysis. The trailers were situated in an area as free as possible from ambient dust contamination.

Test Personnel Responsibilities and Detailed Schedule

Table D-8 lists the key project personnel for this project. Table D-9 lists the various personnel roles and their specific responsibilities. Table D-10 presents a typical test schedule for a 4-week project. A tentative project schedule with dates and activities was provided in the SSTP provided to the company prior to sampling.

Table D-8
Key Project Personnel

Organization	Individual	Responsibility	Phone Number	E-Mail Address
EPRI	Paul Chu	EPRI Project Manager	(650) 855-2812	pchu@epri.com
DOE	Lynn Brickett	DOE Performance Monitor	(412) 386-6574	lynn.brickett@ netl.doe.gov
EPA	C.W. Lee	Project Consultant	(919) 541-7663	lee.chun-wai@ epamail.epa.gov
EERC	Dennis Laudal	Project Manager	(701) 777-5138	dlaudal@undeerc.org
EERC	Jeff Thompson	Principal Investigator	(701) 777-5245	jthompson@undeerc.org
WKU	Wei-Ping Pan	Project Manager	(270) 780-2532	wei-ping.pan@wku.edu
WKU	Kunlei Liu	Principal Investigator	(270)-745-3251	kunlei.liu@wku.edu
QA/QC	David Brekke	QA/QC Manager	(701) 777-5154	dbrekke@undeerc.org
EERC	Jeff Thompson	QA/QC Oversight for WKU	(701) 777-5245	jthompson@undeerc.org

Table D-9
Test Personnel and Responsibilities

Staff Assignment	Responsibilities
Project Manager	EPRI, EPA, DOE, and the EERC developed and approved the overall test program, coordinated all test activities, developed the QA/QC test plan, ensured the project was being completed within budgetary guidelines, provided data interpretation and completed all reporting requirements, maintained communication between all test participants, and assisted with other activities as required.
Principal Investigator	Worked with the project manager to coordinate all test activities, was responsible for maintaining communications between the plant representative and the sampling team, provided input into program decisions made by the funding agencies and the project manager, worked with the field manager to ensure that the objectives for each test program were completed, collected plant data, completed data reduction and provided input into all reports, and assisted in other activities as required.
Field Manager	Coordinated or helped perform all sampling activities; coordinated sampling activities being conducted by the EERC with those being conducted by plant personnel; maintained sample custody records; ensured that sampling was completed so that the objectives of the project were met, including all QA/QC requirements; ensured that all safety requirements were met by the sampling team; provided input into project reports; and assisted other activities as required.
Team Leader	Prepared and operated the OH train and Hg SCEMs, recorded and reduced data, and assisted in sample recovery and other activities as required.
Sampling Technician	Assisted in preparation and operation of the sample trains and assisted in sample recovery and other activities as required.
Project Chemist	Performed all analytical activities at the on-site laboratory, maintained sample custody records, and shipped samples to off-site laboratory when necessary.
Sample Custodian	Maintained sample custody records, transferred samples to on-site laboratory, and assisted in sample recovery and other activities as required.
Plant Engineer	Worked with the field manager and principal investigator to facilitate data and information transfer regarding plant operations.

Table D-10
Typical Test Schedule for a 4-Week Project

Day	Activity
1–2	Travel to site.
3–4	Contact site representative, establish communications, and review unit operation; coordinate crew safety meeting; and prepare and site sampling trailers.
	Set up sample recovery and analysis area, mix fresh reagents as necessary, load sample trains for sampling, set up field blanks, and collect reagent blanks and do reagent blank analyses.
	Set up Hg SCEMs and pretreatment/conversion systems at the proper locations.
	Prepare locations for sampling (i.e., building rails) and conduct preliminary measurements.
	Leak-check sample trains.
5–10	Conduct sampling activities for the first test conditions (individual responsibilities outlined in Table D-9), ensure all blanks and spiked samples meet QA/QC criteria, and ensure all Hg SCEMs are operating properly and giving good data.
11	Pack equipment, package samples for transport to the EERC, and leave site.
4–26	1 operator remains to operate Hg SCEMs for the duration of test period.
19–20	Perform second round of OH analysis.
	Set up sample recovery and analysis area, mix fresh reagents as necessary, load sample trains for sampling, set up field blanks, and collect reagent blanks and do reagent blank analyses.
	Set up Hg SCEMs and pretreatment/conversion systems at the proper locations.
	Prepare locations for sampling (i.e., building rails) and conduct preliminary measurements.
	Leak-check sample trains.
21–26	Conduct sampling activities for the second test conditions (individual responsibilities outlined in Table D-9), ensure all blanks and spiked samples meet QA/QC criteria, and ensure all Hg SCEMs are operating properly and giving good data.
27–28	Pack equipment, package all samples for transport to the EERC, and leave site.

Prior to sampling, 2 days were scheduled for equipment setup. Setup activities included setting up the equipment at the test locations, verifying power at the test locations, and conducting a preliminary velocity traverse (assuming the boiler is operating at or near the target test load). Final coordination with station personnel was done, and safety briefings were held.

Test team personnel arrived at the plant a minimum of 1.5 hr before the start time of the first test run on each of the days scheduled for sampling. Pretest activities included final equipment setup and leak check and verification of target unit operation and communication links between team members, team leaders, and plant personnel.

E
SAMPLE CALCULATIONS

Sample calculations are included for each of the calculated parameters. Data were used from the selective catalytic reduction (SCR) unit inlet location during Day 3 (09/24/2002) from Site S6.

Volume of Gas Sample

Vm(std) = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf

$$Vm(std)\ (dscf) = \frac{K_1 \times Vmc \times Pm}{Tm + 460}$$

$$Vm(std) = \frac{17.64 \times 30.485 \times 1 \times 30.02}{117.7 + 460} = 27.944\,\mathrm{dscf}$$

Where:

K_1 = 17.64°R/in. Hg

Vmc = Vm × Cm = Volume of gas sample as measured by dry gas meter corrected for meter calibration (Cm = meter calibration coefficient) (dcf)

Pm = Meter pressure (in. Hg)

Tm = Meter temperature (°F)

Volume of Water Vapor

Vw(std) = Volume of water vapor in the gas sample, corrected to standard conditions, scf

Vw(std) (scf) = $K_2 \times H_2O(g)$

Vw(std) = 0.04715 × 58.9 = 2.777 scf

Where:

K_2 = $0.04715\ ft^3/g$

$H_2O(g)$ = Mass of liquid collected in impingers and silica gel (g)

Water Vapor in the Gas Stream

Bws = Water vapor in the gas stream, proportion by volume

$$Bws = \frac{Vw(std)}{Vm(std) + Vw(std)}$$

$$Bws = \frac{2.777}{27.944 + 2.777} = 0.0904$$

Dry Molecular Weight

Md = Dry molecular weight of stack gas, lb/lb-mole

$$Md\ (lb/lb\text{-}mole) = 0.440 \times (\%CO_2) + 0.320 \times (\%O_2) + 0.280 \times (\%N_2 + \%CO)$$

$$Md = 0.440 \times 15.2 + 0.320 \times 4.1 + 0.280 \times 80.7 = 30.6\ lb/lb\text{-}mole$$

Where:

$\%(CO_2, O_2, N_2, CO)$ = Percent (CO_2, O_2, N_2, CO) by volume, dry basis

Molecular Weight

Ms = Molecular weight of stack gas, wet basis, lb/lb-mole

$$Ms\ (lb/lb\text{-}mole) = Md \times (1 - Bws) + 18.0 \times Bws$$

$$Ms = 30.6 \times (1 - 0.0904) + 18.0 \times 0.0904 = 29.5\ lb/lb\text{-}mole$$

Average Stack Gas Velocity

Vs = Average stack gas velocity, ft/sec

$$Vs\ (ft/sec) = K_3 \times Cp \times (\Delta p)^{1/2}(avg) \times \left[\frac{Ts + 460}{Ps \times Ms}\right]^{1/2}$$

Vs	=	$85.49 \times 0.84 \times 1.0488 \times \left[\dfrac{704+460}{29.37 \times 29.46}\right]^{1/2} = 87.4\,\mathrm{ft/sec}$

Where:

K_3	=	$85.49\,\mathrm{ft/sec} \times \left[\dfrac{\dfrac{\mathrm{lb}}{\mathrm{lb-mole}} \times \mathrm{in.Hg}}{{}^\circ R \times \mathrm{in.}H_2O}\right]^{1/2}$
Cp	=	Pitot tube coefficient (dimensionless)
Δp	=	Velocity head of stack gas (in. Hg)
$(\Delta p)^{1/2}(\mathrm{avg})$	=	Average of the square root of Δp values
Ts	=	Stack gas temperature (°F)
Ps	=	Stack pressure (in. Hg)

Isokinetic Sampling Rate

I	=	Percent of isokinetic sampling, %
I (%)	=	$\dfrac{K_4 \times (Ts+460) \times Vm(std) \times 144}{Ps \times Vs \times An \times \theta \times (1-Bws)}$
I	=	$\dfrac{0.09450 \times (704+460) \times 27.944 \times 144}{29.37 \times 87.4 \times 0.01986 \times 95 \times (1-0.0904)} = 100.5\%$

Where:

K_4	=	$\dfrac{0.09450\%(\mathrm{in.Hg})(\mathrm{min})}{{}^\circ R \times \sec}$
An	=	Cross-sectional area of nozzle (in.^{2})
θ	=	Total sampling time (min)

Volume of Gas Sample Corrected to 3% O_2

Vm*(std)	=	Volume of gas sample measured by the dry gas meter (Vm(std)), * corrected to 3% oxygen, Nm^3
Vm*(std)	=	$K_5 \times Vm(std) \times \frac{21 - \%O_2}{18}$
Vm*(std)	=	$0.02832 \times 27.944 \times \frac{21 - 4.1}{18} = 0.743\,Nm^3$

Where:

K_5	=	$0.02832\ m^3/ft^3$

Mercury

Hg ($\mu g/Nm^3$)	=	$\frac{\mu g}{Vm*(std)}$
Hg	=	$\frac{2.259}{0.743} = 3.04\ \mu g/Nm^3$ (note: using the Hg^0 from Day 3 SCR inlet)
Particulate Hg	=	Sum of mercury from filter and nozzle rinse
Oxidized Hg	=	Sum of mercury from KCl impingers
Elemental Hg	=	Sum of mercury from H_2O_2 and $KMnO_4$ impingers (note: all H_2O_2 impinger values were nondetects). Since typically less than 5% of the elemental mercury (Hg^0) is trapped in the H_2O_2 impinger, the less-than values were not added to the total Hg^0. Thus the Hg^0 was calculated from the values obtained from the $KMnO_4$ impingers only.

F_d

F_d	=	Value relating gas volume to the heat content of the fuel
F_d (dscf/10^6 Btu)	=	$10^6 \times \frac{[(K_6 \times \%H) + (K_7 \times \%C) + (K_8 \times \%S) + (K_9 \times \%N) - (K_{10} \times \%O_2)]}{HV}$
F_d	=	$10^6 \times \frac{[(3.64 \times 5.23) + (1.53 \times 70.74) + (0.57 \times 0.86) + (0.14 \times 1.52) - (0.46 \times 9.46)]}{11{,}936}$
	=	10,357 dscf/Btu

Where:

$K_6 = 3.64 \dfrac{\text{dscf}}{\%\text{H} \times \text{lb}}$

$K_7 = 1.53 \dfrac{\text{dscf}}{\%\text{C} \times \text{lb}}$

$K_8 = 0.57 \dfrac{\text{dscf}}{\%\text{S} \times \text{lb}}$

$K_9 = 0.14 \dfrac{\text{dscf}}{\%\text{N} \times \text{lb}}$

$K_{10} = 0.46 \dfrac{\text{dscf}}{\%\text{O}_2 \times \text{lb}}$

HV = Heating value of coal (Btu/lb)

% (H, C, S, N, O) = Percent (H, C, S, N, O) in coal (as-received from ultimate analyses)